MIXED LAYER EVOLUTION AND MESOSCALE VARIABILITY IN THE LABRADOR SEA

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LONG TERM GOALS

Our long-term goals are to understand the mesoscale dynamics of deep convection, and the links between the surface mixed layer, the underlying thermocline, the upper level circulation, and surface heat fluxes.

OBJECTIVES

We want to examine the mesoscale variability during and immediately following deep convection in the Labrador Sea. We hope to track eddies formed by the baroclinic instability of the chimney and the rim current. We will monitor the evolution of the heat content and the turbulent heat fluxes in the water column before, during, and after deep convection.

APPROACH

We use acoustically tracked, neutrally buoyant RAFOS floats to "tag" and follow water in the Labrador Sea during deep convection events. The floats obtain three navigation fixes per day from four moored sound sources, allowing us to explore Lagrangian pathways and mesoscale variability. During the convection season, between 150-200 temperature (T, to 0.001 ^{o}C resolution) and pressure (P, to 0.5 dbar) measurements are collected each day. Knowing the depth response of the float to vertical water velocities (w), we can determine the vertical velocity of the water from the floats' pressure record. Combining precise temperature data with these velocities allows us to estimate the turbulent heat flux $<w'T'>$. In addition, we have modified the floats by adding a 30 cm^3 *vo*lume *cha*nging (vocha) mechanism. This vocha is capable of changing the density of the float by about 2 kg m^{-3} at discrete 0.15 kg m^{-3} intervals. We have used this capability by sending the float on repeated profiles of the water column collecting T and P, allowing us to monitor the evolution of the mixed layer depth and heat content. It is important to realize that these measurements are being made in a Lagrangian framework, moving with the water. Difficulties accounting for heat budgets from a fixed, stationary position are thus avoided.

ACCOMPLISHMENTS

The four sound sources used for float navigation and four convection RAFOS floats were deployed from the C.S.S. Hudson in the fall of 1996. During the winter 1997 cruise of the R/V Knorr an additional 18 floats were launched, with 9 more from the spring 1997 cruise of the C.S.S. Hudson. We did, however suffer an unexpectedly large failure rate; out of the 31 floats launched, 14 were not heard from again or returned no useful data. An additional 14 floats

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surfaced prematurely as a fail-safe response to the float's on-board computer locking-up. After a summer's worth of intensive laboratory and cold room testing, we have pin-pointed the problem and have implemented repairs. Testing and confirmation will continue until the next and final cruise, when the remaining 20 floats will be launched from the upcoming January 1998 cruise of the R/V Knorr.

In spite of our difficulties, we did obtain 60 vertical profiles to almost 1000 m depth, 11 float-months of subsurface Lagrangian trajectories, and over 400 *T/P* time-series. The acoustic navigation is working very well, even in the wind-roughened, surface-trapped sound channel found in the Labrador Sea winter.

SCIENTIFIC/TECHNICAL RESULTS

The RAFOS floats have monitored mixed layer cooling prior to convection (Fig. 1), where the 100 m deep mixed layer cooled by 1 ^{o}C in 30 days, indicating a surface heat flux of 150 W m^{-2}. During the early convection season (mid-February to early March), the mixed layer deepened from 600 m to in excess of 1000 m (the maximum extent of our instrument) (Fig. 2). The change in water column heat content over these 20 days results in a heat flux of 340 W m^{-2}. At this same time, we also observed downward vertical velocities of nearly near 8 cm s^{-1}. Preliminary correlations with temperature perturbations give turbulent heat fluxes around 150 W m^{-2}, but more analysis is required to improve these estimates. Finally, floats deployed near Greenland after convection show eddies, both cyclonic and anticyclonic, spinning around the edge of the basin, with one float experiencing over 20 revolutions (Fig. 3). The relative vorticity of this eddy was 0.3 to 0.4 times that of the coriolis parameter *f*.

We have demonstrated the capability of the modified RAFOS float to measure changes of heat content of the mixed layer, and we are able to use the *T* and *P* time-series data to estimate turbulent heat fluxes. We are presently working with surface flux data obtained from Dr. Peter Guest of the Naval Postgraduate School, and will collaborate with him in float/field data intercomparisons.

IMPACT FOR SCIENCE

We consider the profiling RAFOS float to be an effective tool for the monitoring the evolution of the surface waters in a Lagrangian framework. The float, with minimal changes in hardware and software, can also monitor obduction/subduction of thermocline waters before/after the winter cooling season.

TRANSITIONS

No technology transfers or transitions were accomplished this year pertaining to this project.

RELATED PROJECTS

RAFOS floats are currently being deployed as part of the Atlantic Climate Change Experiment (ACCE) in the extension region of the North Atlantic Current (NAC). Our goals in this project are (i) to explore the structure of the boundary between the subpolar and subtropical gyres, and (ii) the sites and mechanisms of exchange. The floats used are isopycnal, and measure temperature, pressure, and oxygen for their nearly two-year missions. One sound source deployed as part of the deep convection experiment in the Labrador Sea provides acoustic navigation in the western subpolar basin. We anticipate some floats deployed in the ACCE

program may be entrained by the Irminger or Greenland Currents and thus map out warm-water pathways into the Labrador Sea.

PUBLICATIONS

Rossby, T. 1997: Numerical experiments with a fluid heated nonuniformly from below. *Tellus,* (resubmitted).

The LABSEA Group, 1997: The Labrador Sea Deep Convection Experiment. *Bull. Amer. Meteor. Soc.* (in preparation).

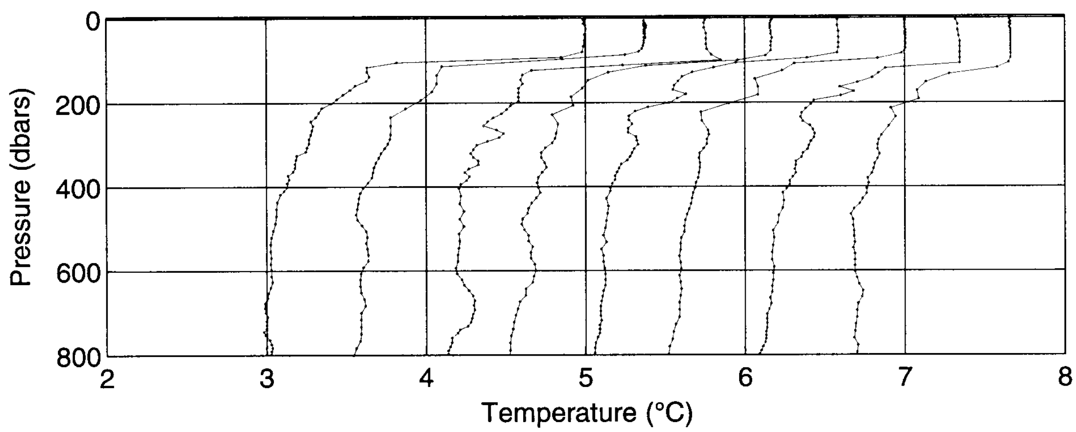

Figure 1. Temperature profiles from RAFOS float 375, launched in October, 1996. The first six profiles were made at 3 day intervals, the last two profiles were at 5 day intervals. The steady cooling and gradual deepening of the mixed layer can be clearly seen, from which an estimate of a 150 W m^{-2} surface heat flux can be made. The profiles have been offset to one another by 0.5 °C.

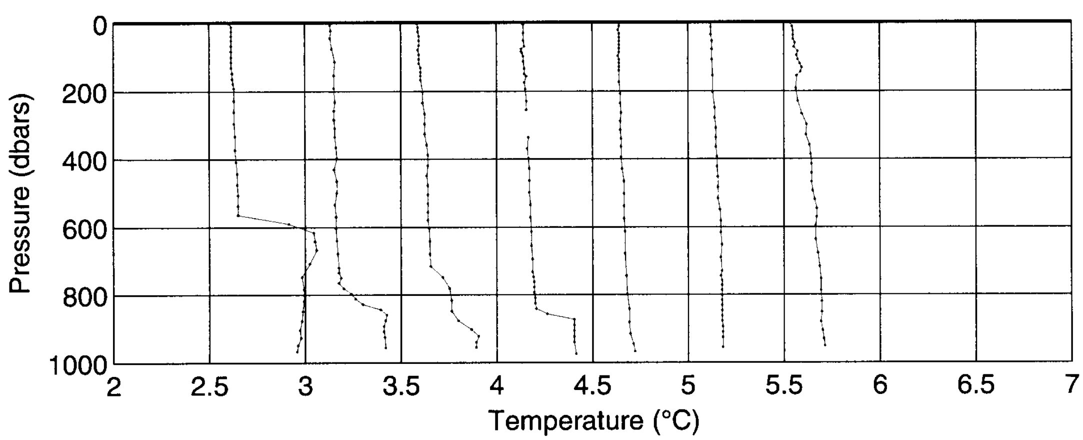

Figure 2. Temperature profiles from RAFOS float 388, launched in February, 1997. The profiles were made at 5 day intervals. The mixed layer deepening and concurrent heat loss over the first 20 days of the record can be attributed to a surface heat flux of 340 W m^{-2}. The profiles have been offset to one another by 0.5 °C.

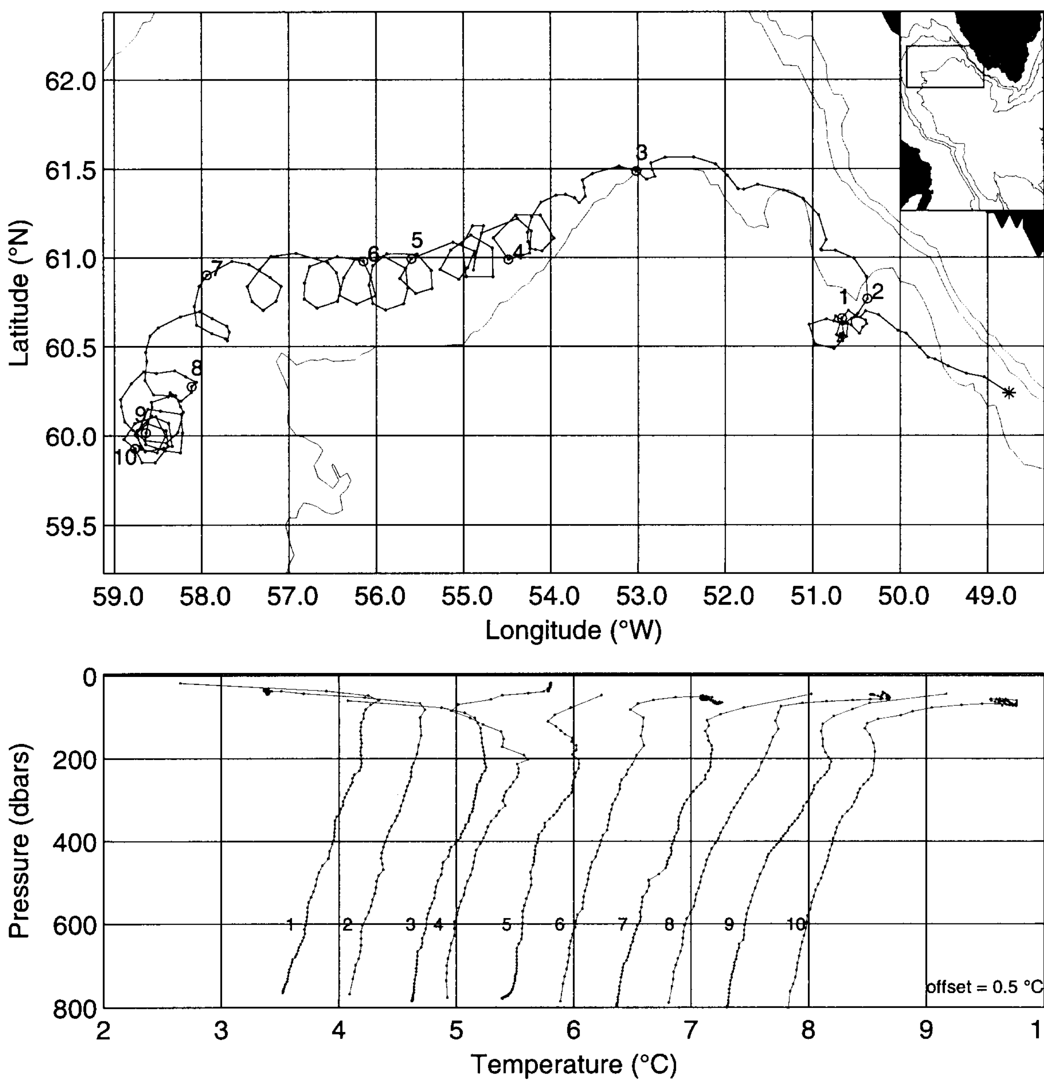

Figure 3. Trajectory of RAFOS float 404, launched off Greenland in May, 1997. The float was tracked 3 times a day, and was trapped in a cyclonic eddy having relative vorticity 0.3 to 0.4 f. The numbers along the float path denote positions of the weekly vertical temperature profiles shown in the bottom panel. The profiles have been offset to one another by 0.5 °C.